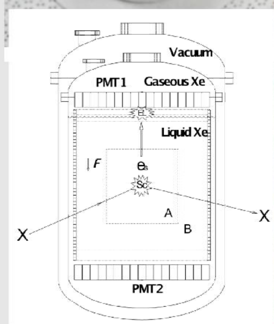
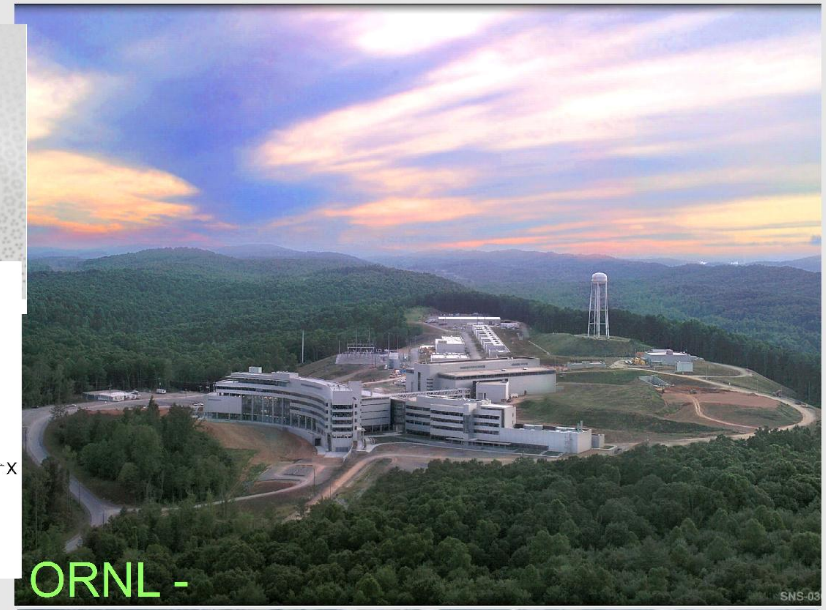
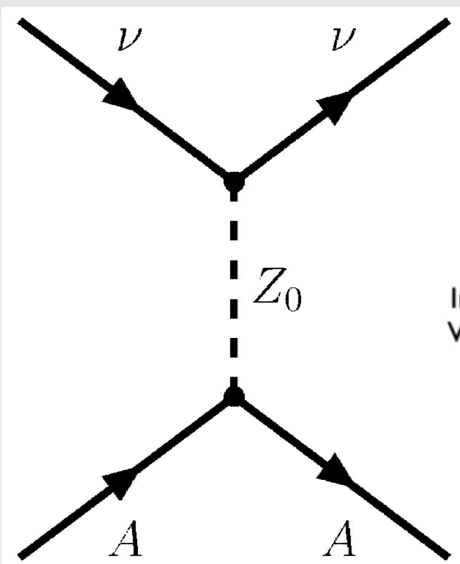
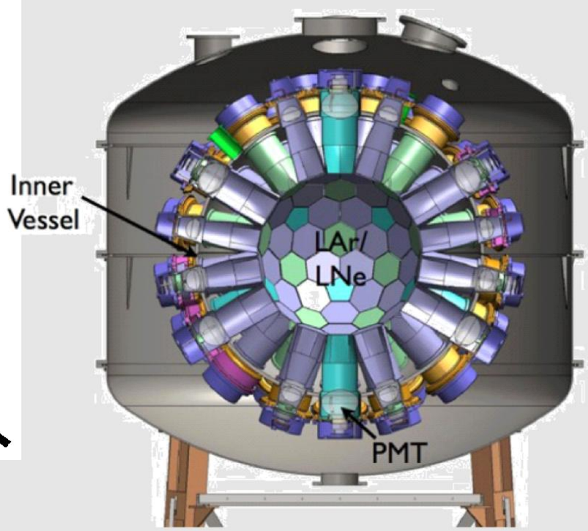
Opportunities for a CEvNS experiment on a π DAR beamline.

Outline:
- Physics, Motivation
- Fermilab/SNS
    - sources
    - detectors
    - sensitivities
- Summary



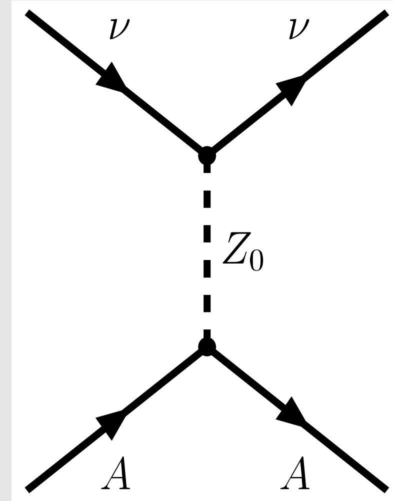






The CEνNS process

Coherent Elastic ν–Nucleus Scattering: νA→νA :

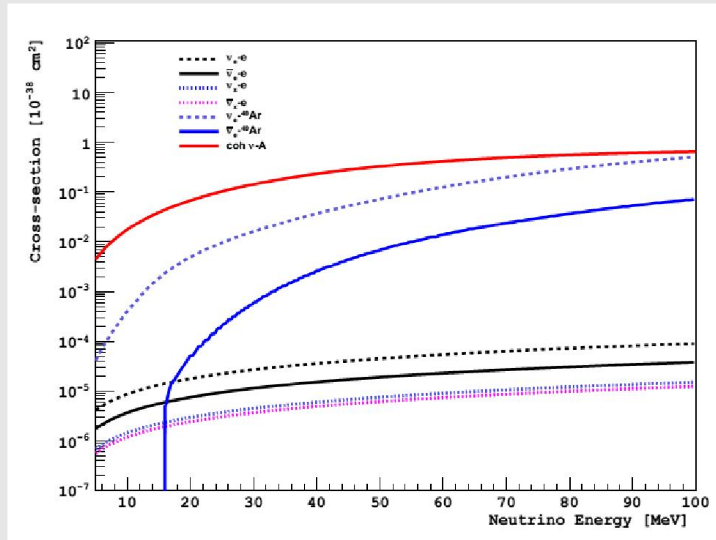


- neutrino scatters with low momentum transfer coherently, elastically from entire nucleus. For large nucleus, R_N~few fm, coherence requires:

$$E_\nu \lesssim \frac{hc}{R_N} \cong 50 \text{ MeV}$$

Cross section is big and goes as A^2 ....

$$\frac{d\sigma}{dE} = \frac{G_F^2}{4\pi}[(1-4\sin^2\theta_w)Z-(A-Z)]^2 M\left(1-\frac{ME}{2E_\nu^2}\right)F(Q^2)^2$$



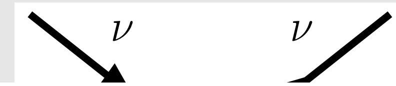
... but recoil energy is small:

$$E_r^{\max} \simeq \frac{2E_\nu^2}{M} \simeq 50 \text{ keV}$$

... so, alas, CEνNS has never been measured

The CEνNS process

Coherent Elastic ν–Nucleus Scattering: νA→νA :



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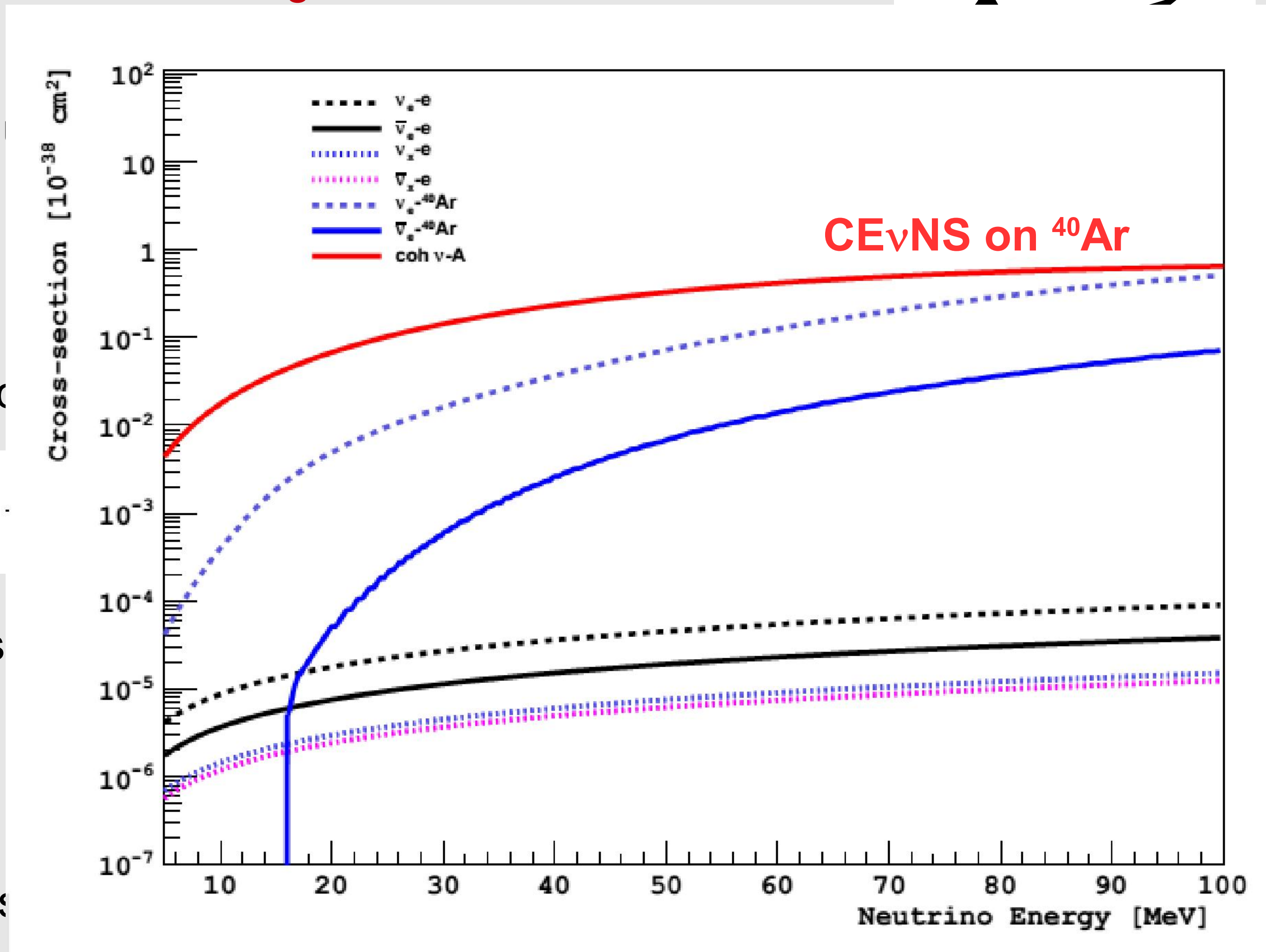

The CEνNS process

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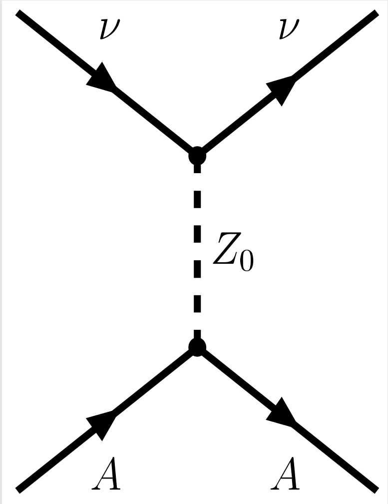

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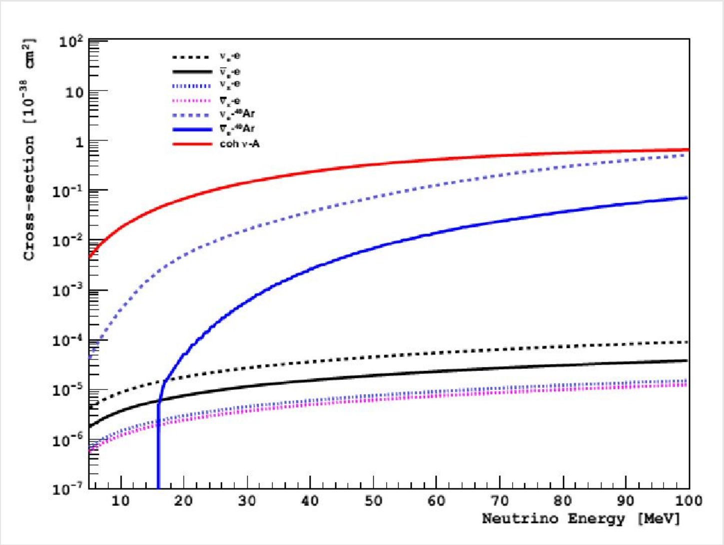


... but recoil energy is small:

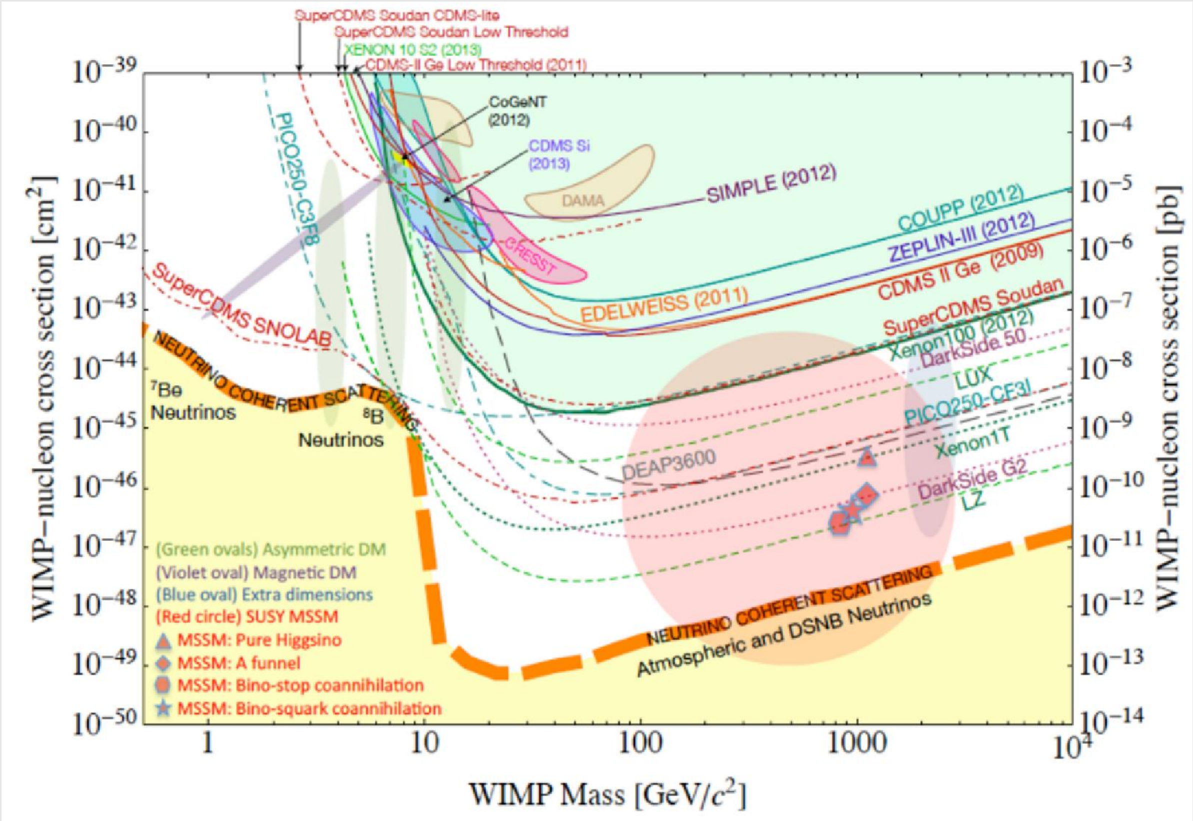
$$E_r^{\max} \simeq \frac{2E_\nu^2}{M} \simeq 50 \text{ keV}$$

... so, alas, CEνNS has never been measured

CEνNS physics

The physics is rich and relevant
- Dark Matter: Important background for 10-ton scale searches
- Supernovae: Expected to be important in core-collapse SN and possible SN detection channel.
- ν oscillations: A possible ν_s detection reaction
- Standard Model tests: $\sin^2\theta_w$ perhaps

Possible related/additional physics topics:
- ν-induced neutrons, gammas, fission
- low-mass DM search with same detectors (large mass near hot sources)



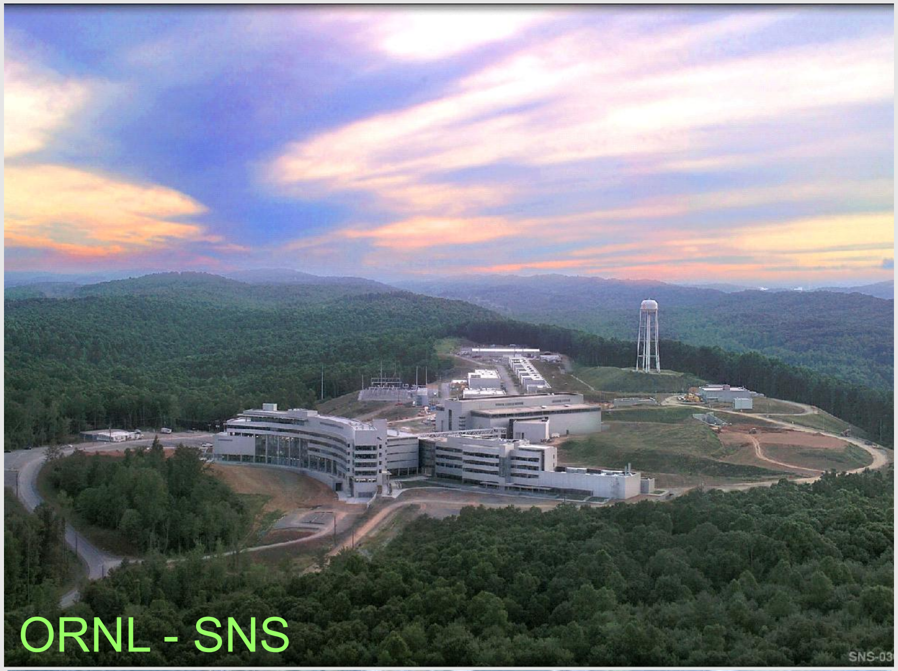
How to measure CEνNS

Need:
- intense ~50 MeV ν source
- sizable (10-1000 kg), low-threshold (~10keVnr) detector
- control, understand, measure (and repeat) backgrounds

A phased approach is wise, eg:
- measure, control backgrounds
- discovery of CEνNS
- measure, control backgrounds, optimize detector(s)
- high-precision measurement of CEνNS

- Current efforts using π DAR beams in US:
  - COHERENT (ORNL) using SNS
  - CENNS (Fermilab) using BNB

(not covering reactor/rad. source ν exps)



Collaborations

- COHERENT,
  focused on SNS efforts

Coherent Scattering Investigations at the Spallation Neutron Source: a Snowmass White Paper

arXiv:1310.0125v1 [hep-ex] 1 Oct 2013

October 2, 2013

D. Akimov[11], A. Bernstein[9], P. Barbeau[3], P. Barton[8], A. Bolozdynya[11], B. Cabrera-Palmer[19], F. Cavanna[23], V. Cianciolo[16], J. Collar[2], R.J. Cooper[6], D. Dean[16], Y. Efremenko[21,11], A. Etenko[11], N. Fields[2], M. Foxe[18], E. Figueroa-Feliciano[12], N. Fomin[21], F. Gallmeier[16], I. Garishvili[21], M. Gerling[19], M. Green[13], G. Greene[21], A. Hatzikoutelis[21], R. Henning[13], R. Hix[16], D. Hogan[1], D. Hornback[16], I. Jovanovic[18], T. Hossbach[17], E. Iverson[16], S.R. Klein[8], A. Khromov[11], J. Link[22], W. Louis[10], W. Lu[16], C. Mauger[10], P. Marleau[19], D Markoff[14], R.D. Martin[20], P. Mueller[16], J. Newby[16], J. Orrell[17], C. O'Shaughnessy[13], S. Penttila[16], K. Patton[15], A.W. Poon[8], D. Radford[16], D. Reyna[19], H. Ray[5], K. Scholberg[3], V. Sosnovtsev[11], R. Tayloe[6], K. Vetter[8], C. Virtue[7], J. Wilkerson[13], J. Yoo[4], C.H. Yu[16]

- CENNS,
  Fermilab effort

PHYSICAL REVIEW D **89**, 072004 (2014)

A method for measuring coherent elastic neutrino-nucleus scattering at a far off-axis high-energy neutrino beam target

S. J. Brice,[1] R. L. Cooper,[2,*] F. DeJongh,[1] A. Empl,[3] L. M. Garrison,[2] A. Hime,[4] E. Hungerford,[3] T. Kobilarcik,[1] B. Loer,[1] C. Mariani,[5] M. Mocko,[4] G. Muhrer,[4] R. Pattie,[6] Z. Pavlovic,[4] E. Ramberg,[1] K. Scholberg,[7] R. Tayloe,[2] R. T. Thornton,[2] J. Yoo,[1] and A. Young[6]

[1]*Fermi National Accelerator Laboratory, Batavia, Illinois 60510, USA*
[2]*Indiana University, Bloomington, Indiana 47405, USA*
[3]*University of Houston, Houston, Texas 77204, USA*
[4]*Los Alamos National Laboratory, Los Alamos, New Mexico 87545, USA*
[5]*Virginia Tech, Blacksburg, Virginia 24061, USA*
[6]*North Carolina State University, North Carolina 27695, USA*
[7]*Duke University, Durham, North Carolina 27708, USA*
(Received 25 November 2013; published 3 April 2014)

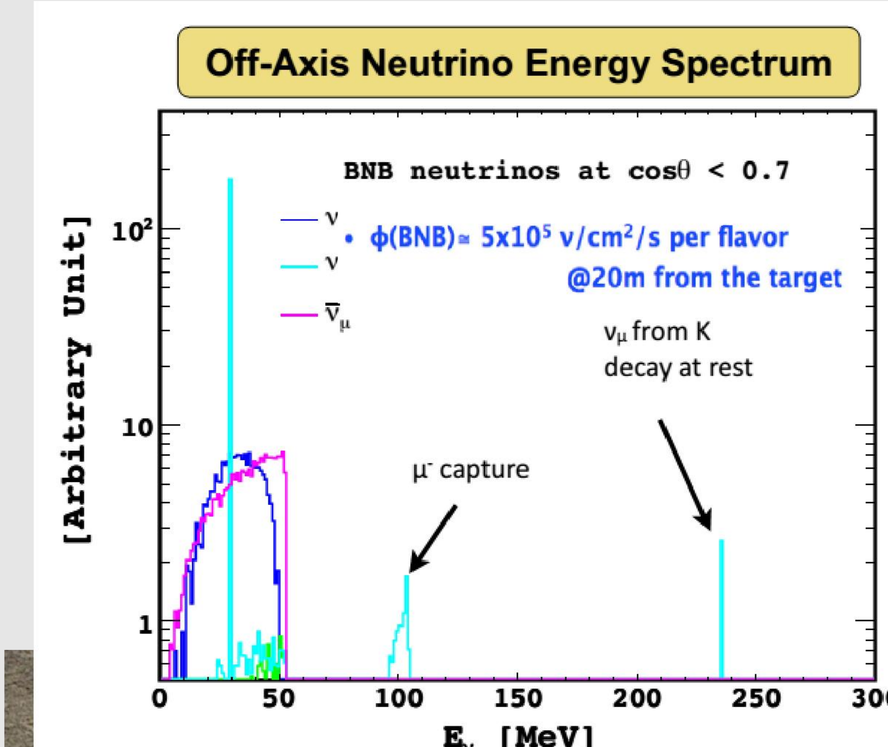
- much crossover, cooperation

Sources for CEνNS

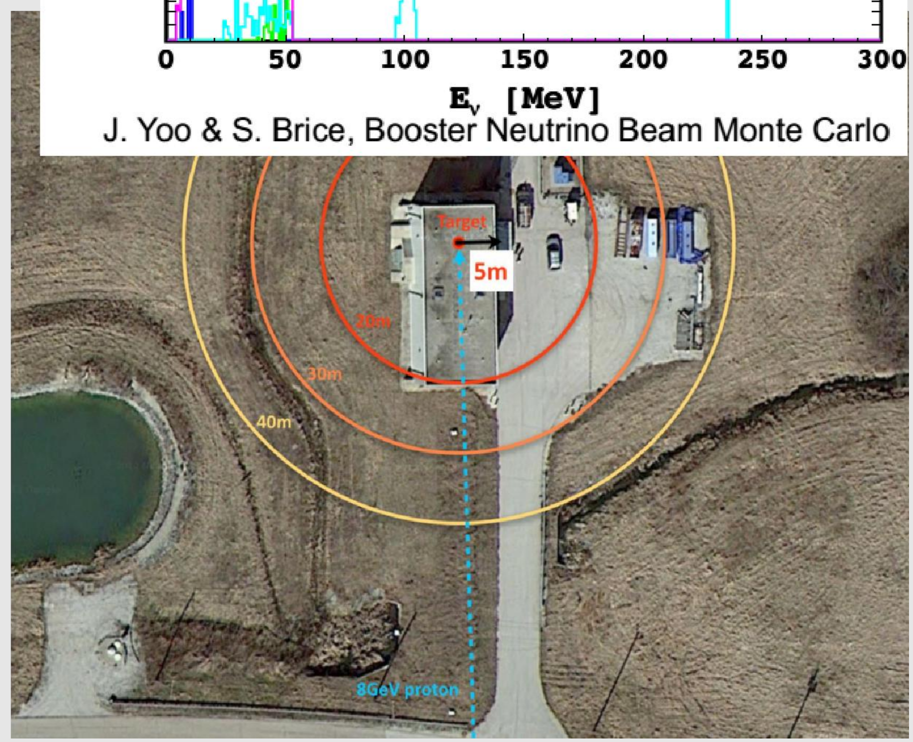
BNB at Fermilab:

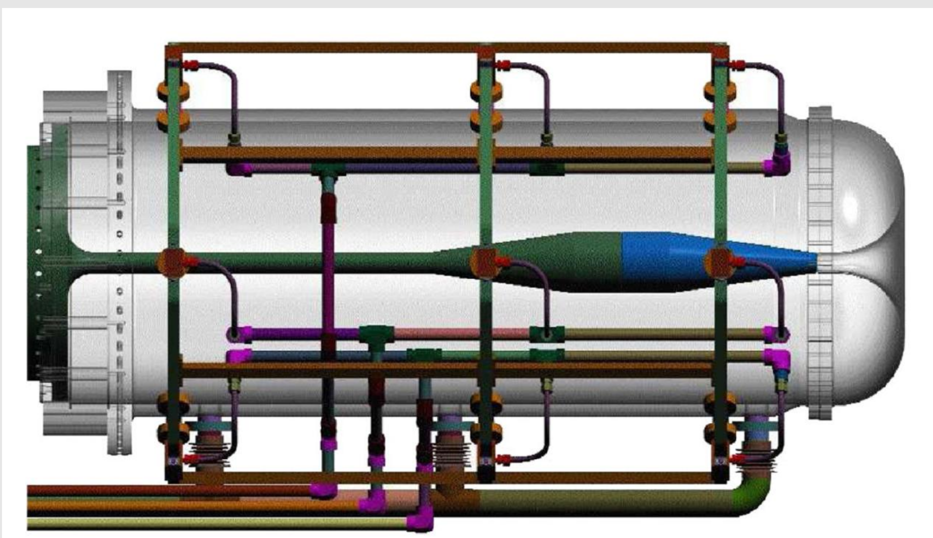
- 8 GeV protons@~5Hz
- ~1E-5 duty factor (w/τ_μ)
- up to 32kW beam power
- built for π DIF (~1GeV ν) to MiniBooNE
- substantial π DAR flux at ~90° with low DIF flux

- open space ~5m from target (~10m with shielding, building etc)



J. Yoo & S. Brice, Booster Neutrino Beam Monte Carlo

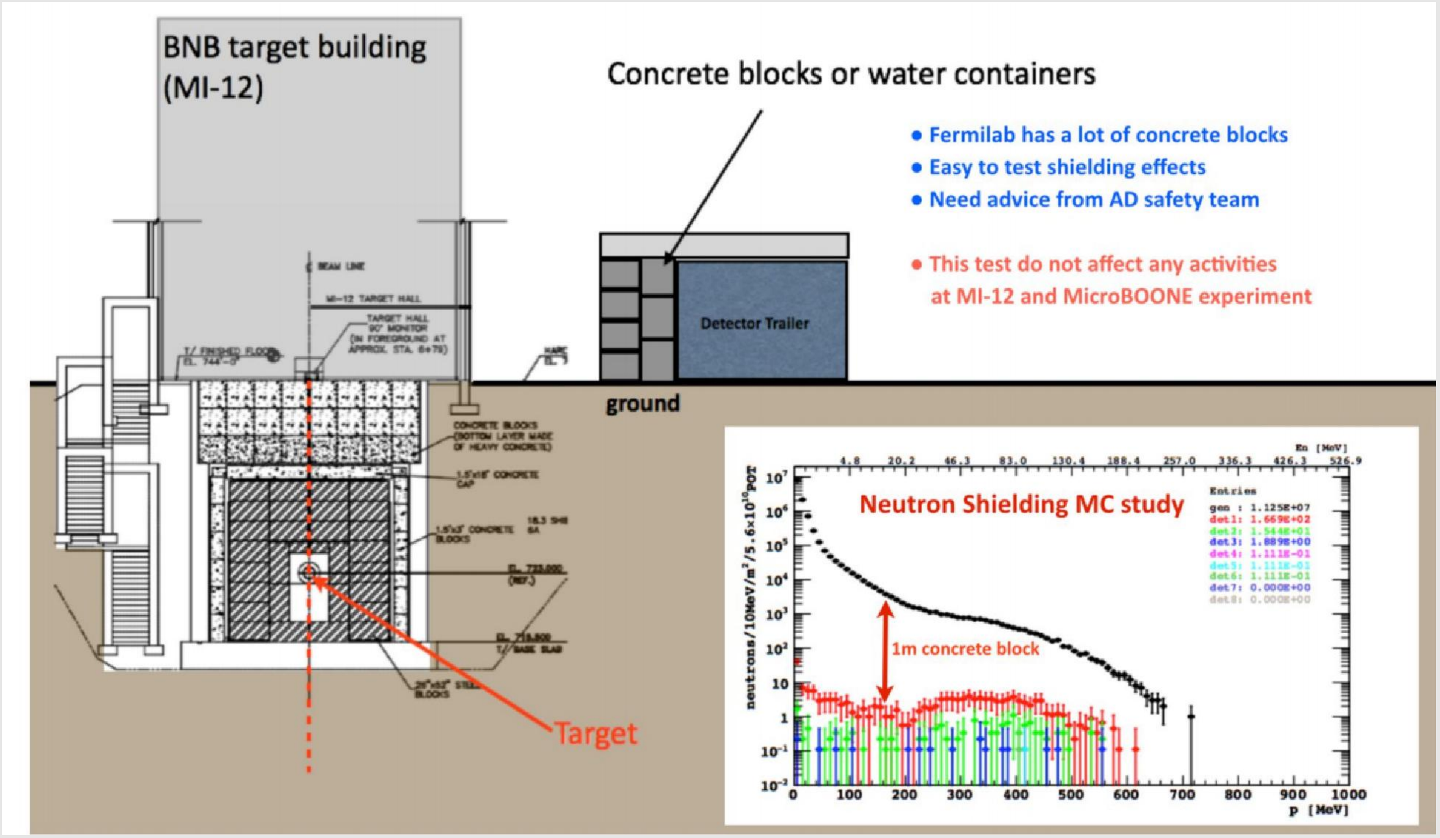




Sources for CEνNS

BNB at Fermilab:

- background measurement + simulations indicate ~5m of shielding needing for beam related neutrons (also enough for beam-unrelated bkgs)



- need to verify this with SciBath+ prototype shielding design.

- planning to do in summer '15

- (also of interest to CAPTAIN exp)

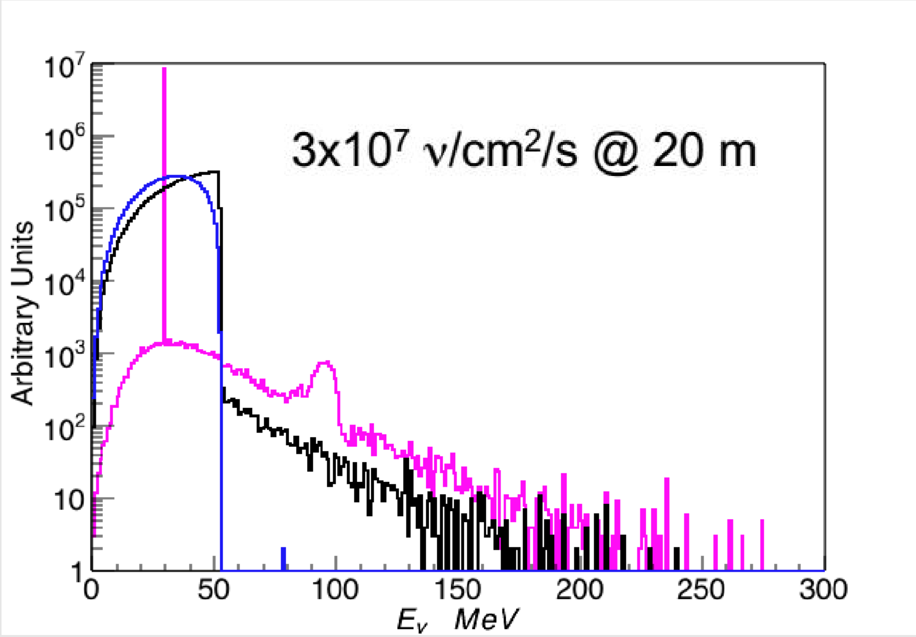
Sources for CEνNS

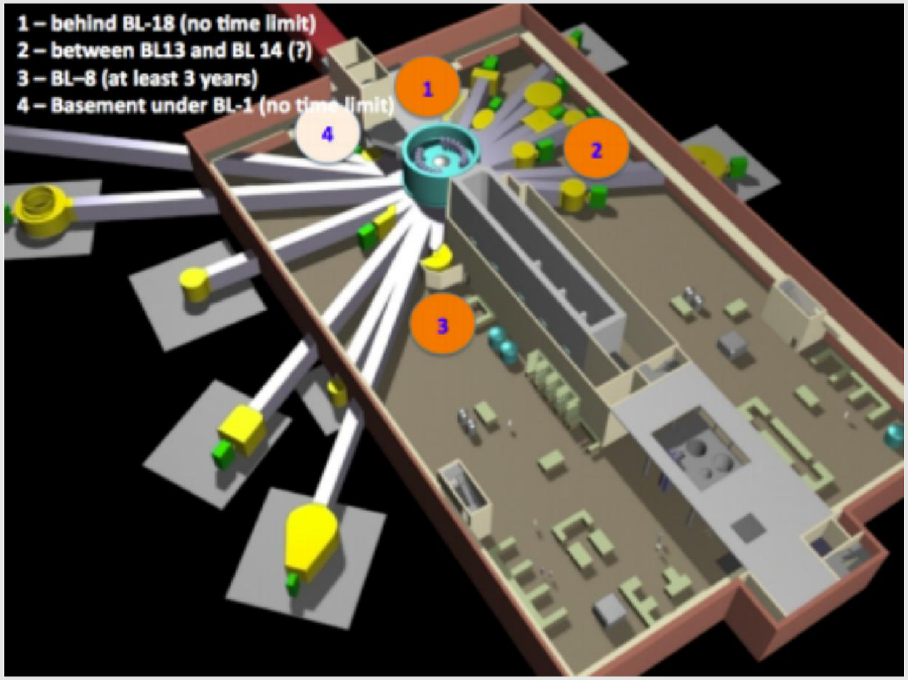
SNS at ORNL:

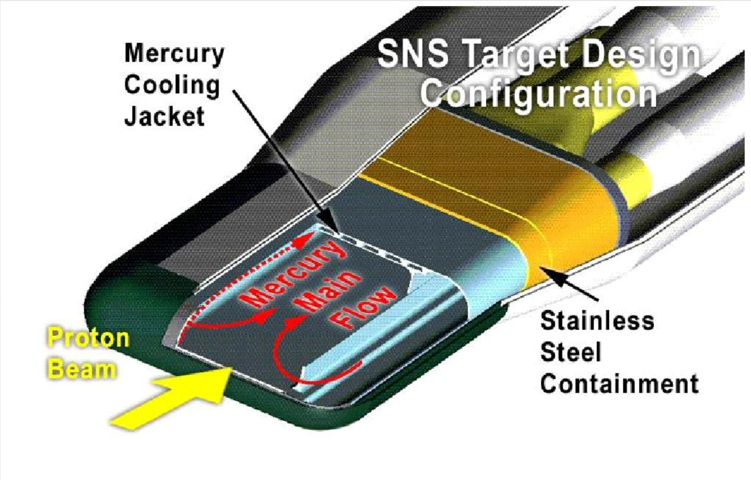
- ~1GeV protons@60Hz
- ~1E-4 duty factor (w/τ_μ)
- up to ~1.4MW beam power

- built for spallation neutron prod. with Hg target
- large π DAR flux at with low DIF flux

- multiple sites (with varying floor/head space) at 15-20m inside building...
- and starting at 30m outside...



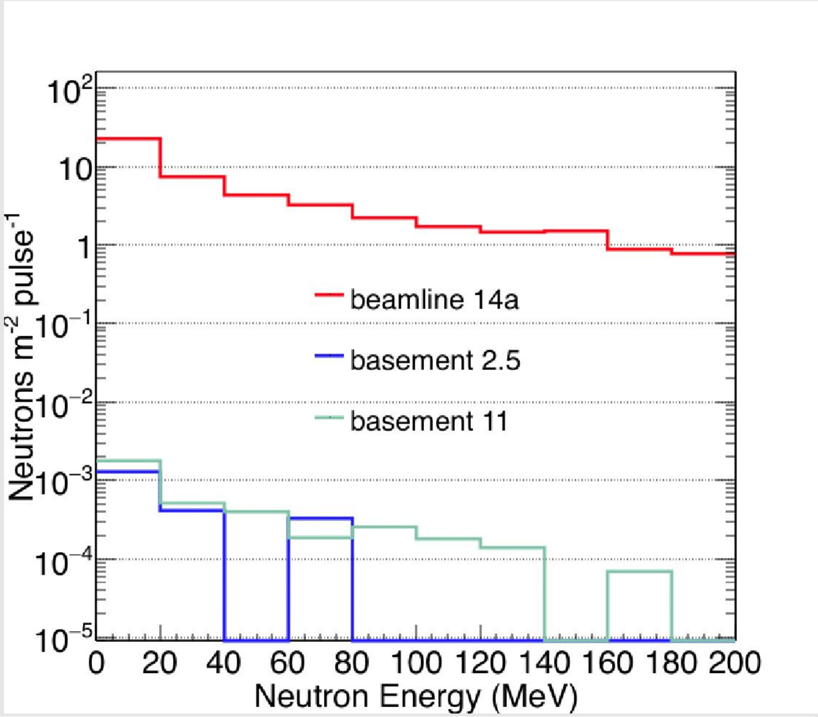


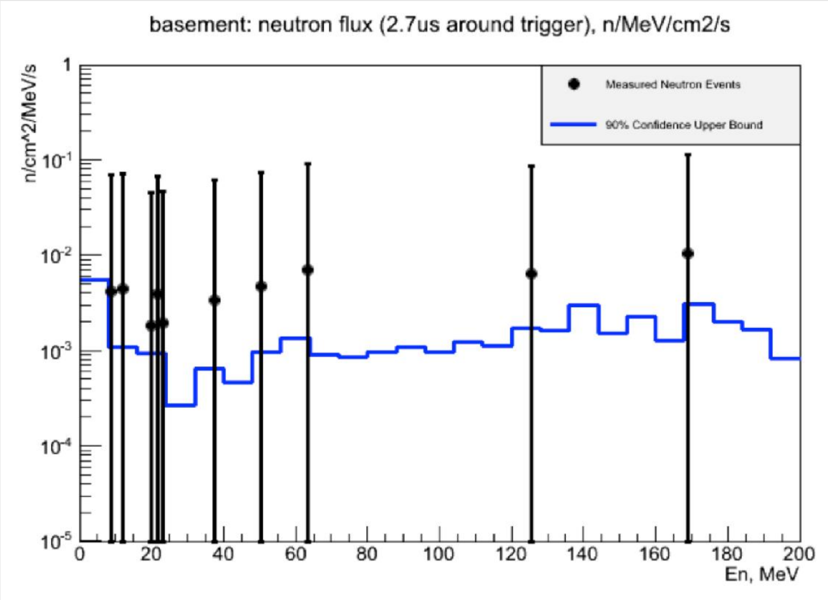


Sources for CEνNS

SNS at ORNL:

- many recent neutron background measurements..
- indicate low backgrounds in several candidate locations



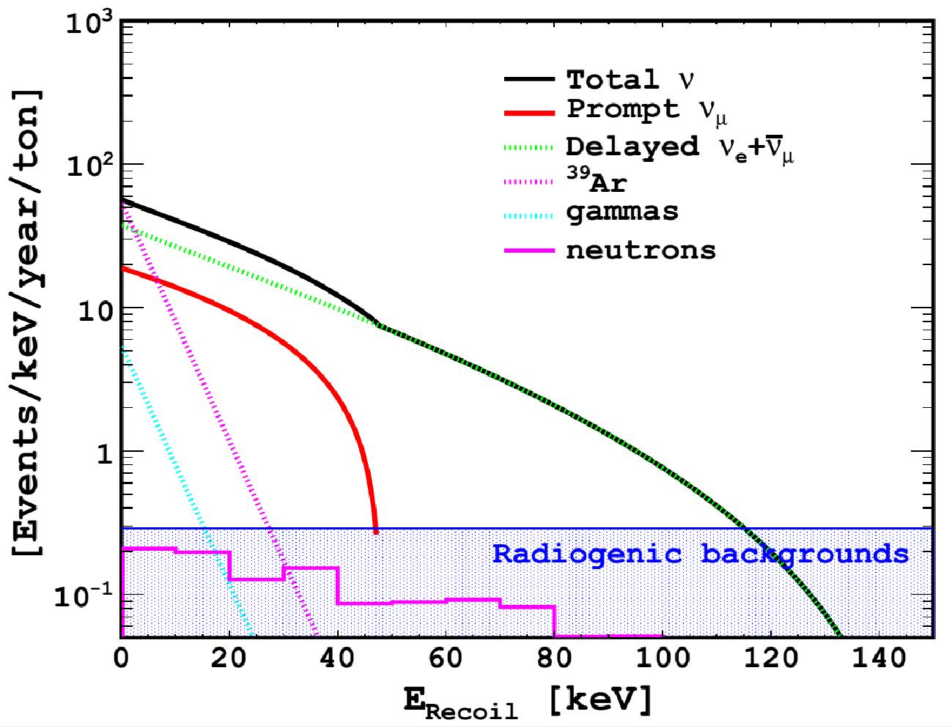


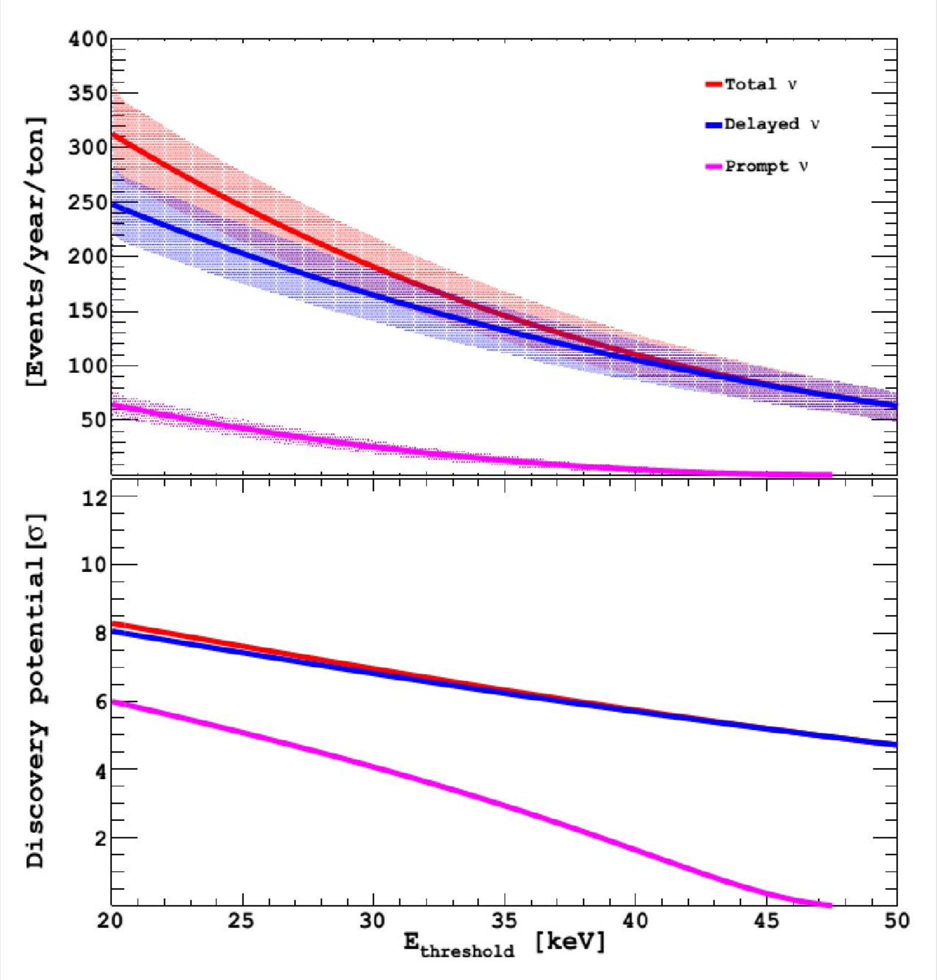
sensitivity

Fermilab effort:

- 500kg miniCLEAN provides ~100 CEvNScevents/year

- 1 year-ton provides 7s discovery





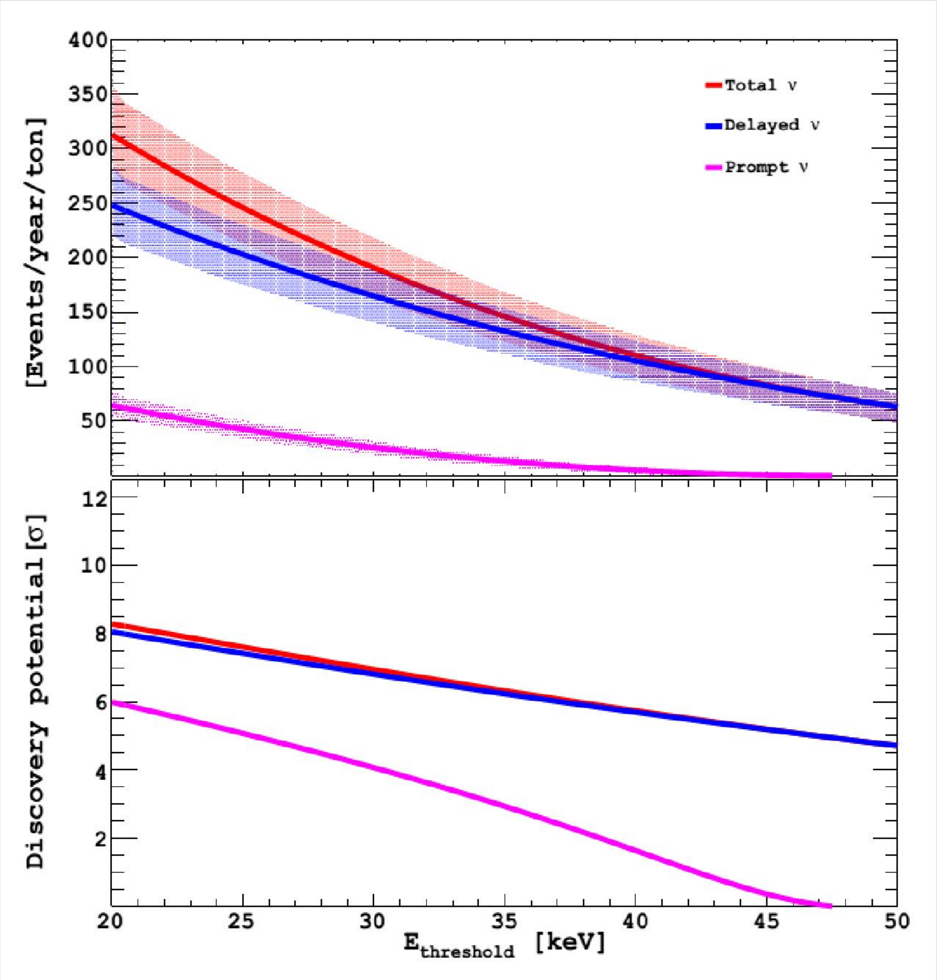
errors

Fermilab effort:

- 500kg miniCLEAN provides ~100 CEvNScevents/year

- 1 year-ton provides 7s discovery

	Uncertainty	ETC
Neutrino flux	9%	
Leff of LAr	7.5%	
High energy neutrinos	$<1\%$	
Beam-induced neutrons	$<1\%$	
Cosmogenic neutrons	$<1\%$	
^{39}Ar and gammas	$<0.5\%$	PSD
Radiogenic backgrounds	$<1\%$	use beam-off data
Total uncertainty	**12%**	$E_{th} \geq 25\,\mathrm{keV}_r$



detector technology

SNS:

CsI

- eventually ~14kg
- ~7 keVnr energy threshold
- ~500 events/yr@20m
- possible first obs at SNS

Coherent neutrino-nucleus scattering detection with a CsI[Na] scintillator at the SNS spallation source

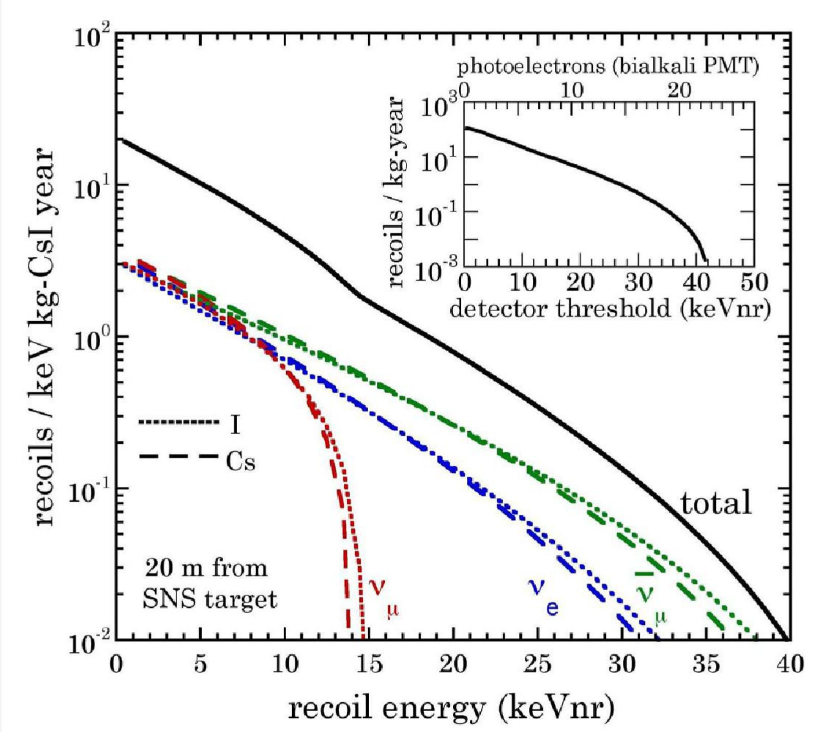
J.I. Collar[1], N.E. Fields[1], M. Hai[1,†], T.W. Hossbach[2], J.L. Orrell[2], C.T. Overman[2], G. Perumpilly[1], B. Scholz[1]

[1]*Enrico Fermi Institute, Kavli Institute for Cosmological Physics, and Department of Physics, University of Chicago, Chicago, IL 60637, USA*

[2]*Pacific Northwest National Laboratory, Richland, WA 99352, USA*

[†]*Present address: College of Engineering, Carnegie Mellon University, Pittsburgh, PA 15213, USA*

- 2kg currently deployed at SNS and running at 20m location, studying backgrounds esp NIN



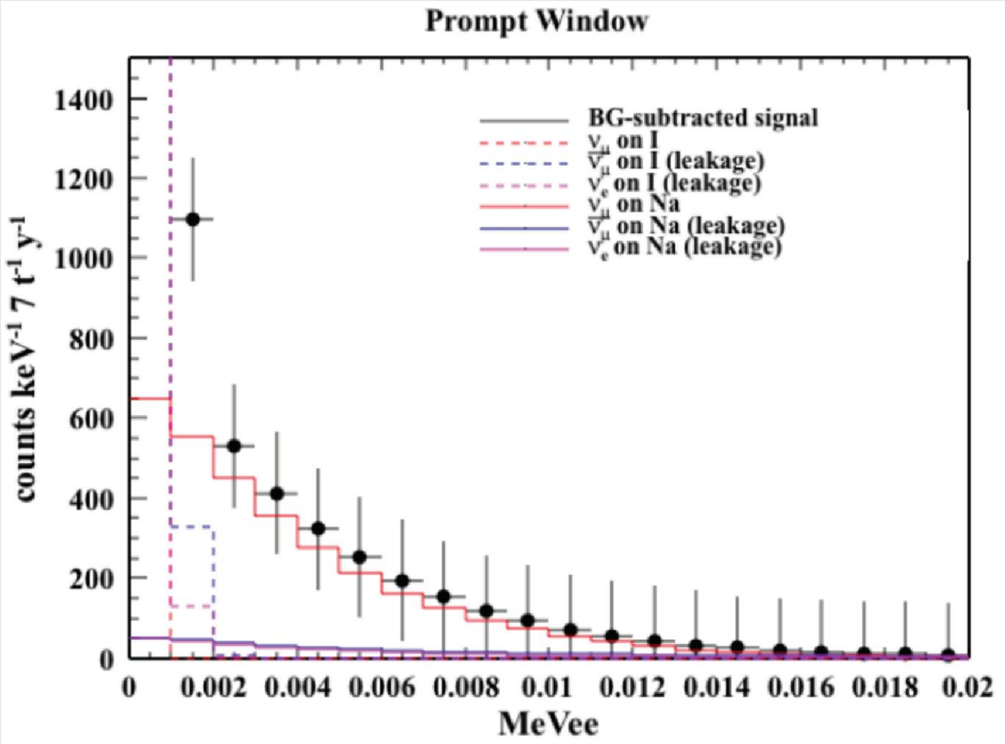
detector technology

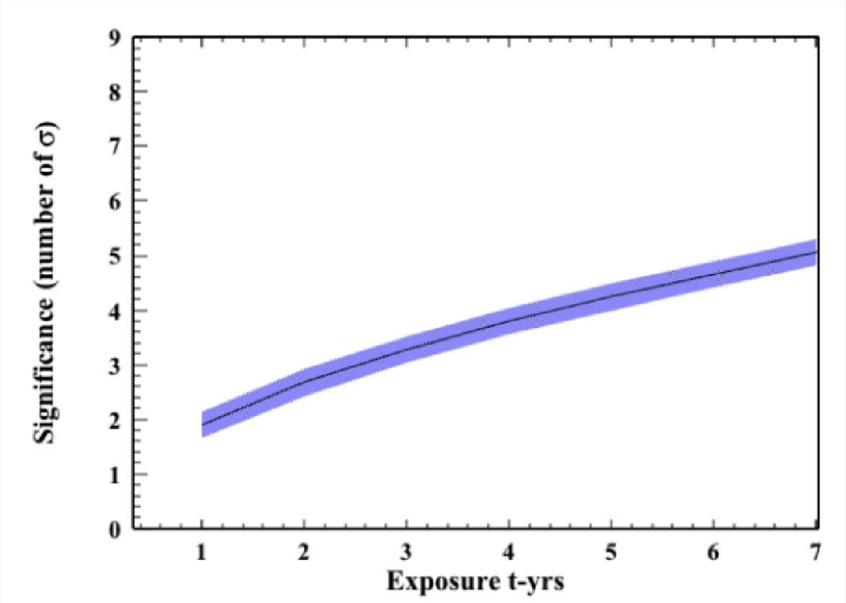
SNS:

NaI

- possibility of ~few tons of NaI, portal monitoring, detectors, ~70 keVnr threshold

- under study for a possible early measurement
(*or active shielding.. perhaps?*)



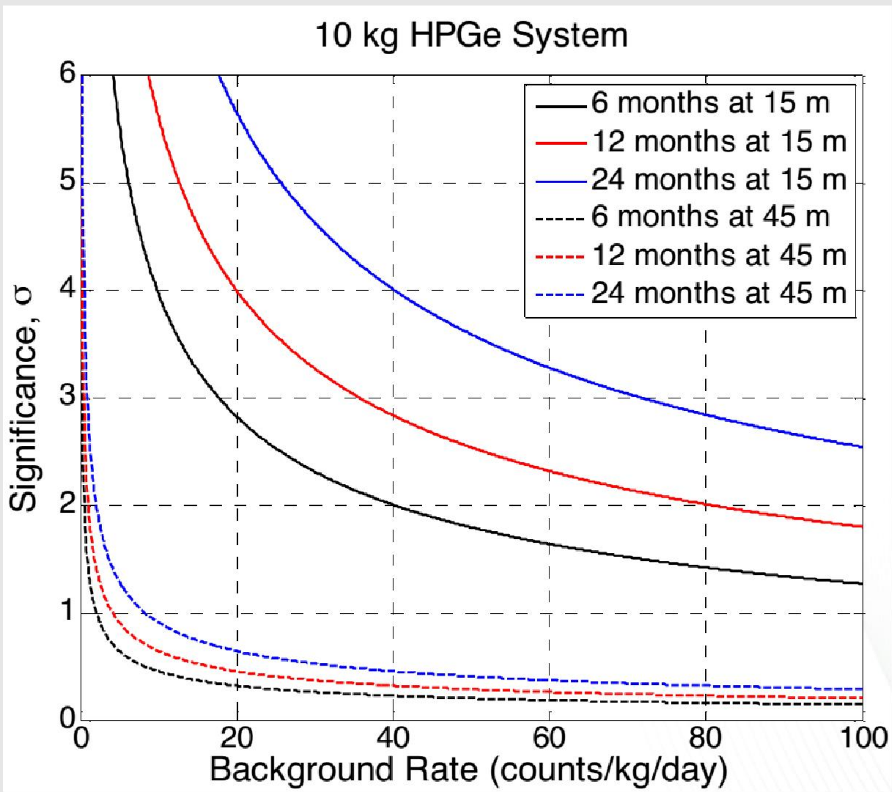


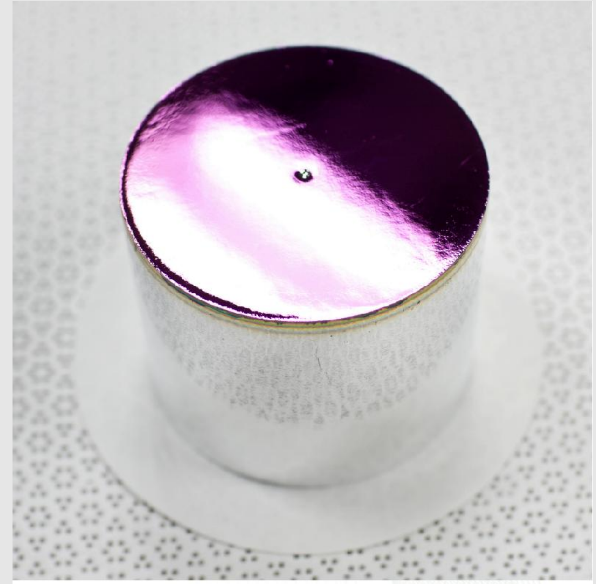
detector technology

SNS:

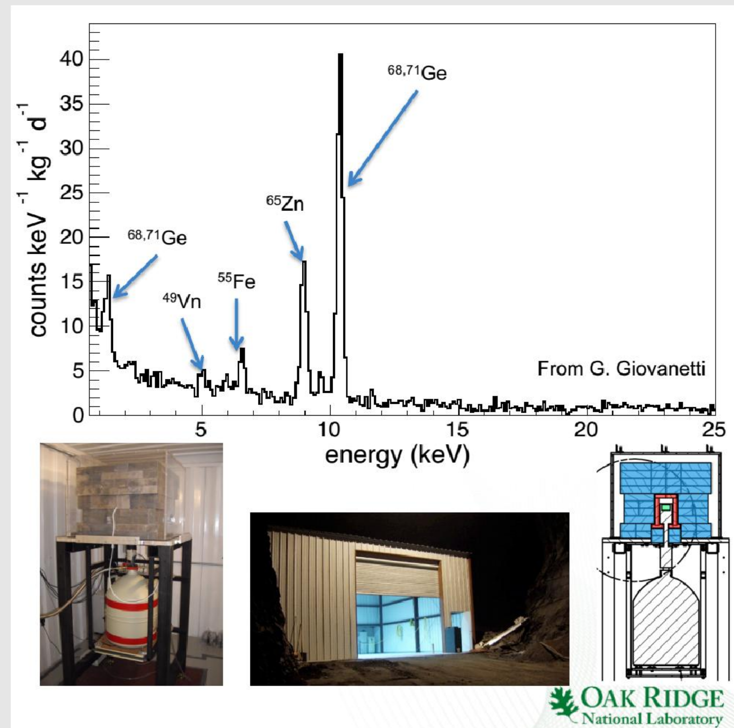
Ge

- eventually ~20kg
- ~1 keVnr energy threshold
- ~2000 events/y
- possible redeployment of MJD at SNS ~10kg





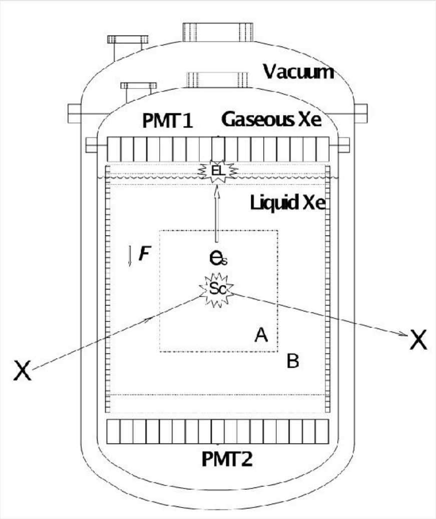
LBL PPC Detector

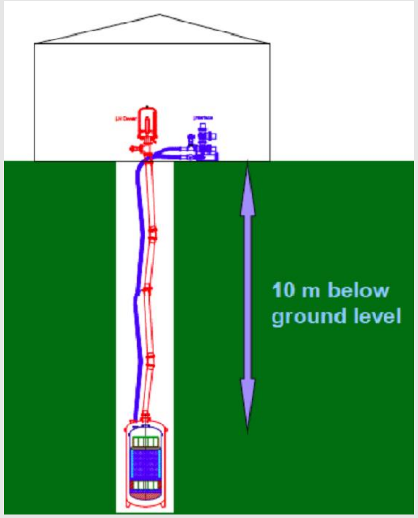


more detector technology

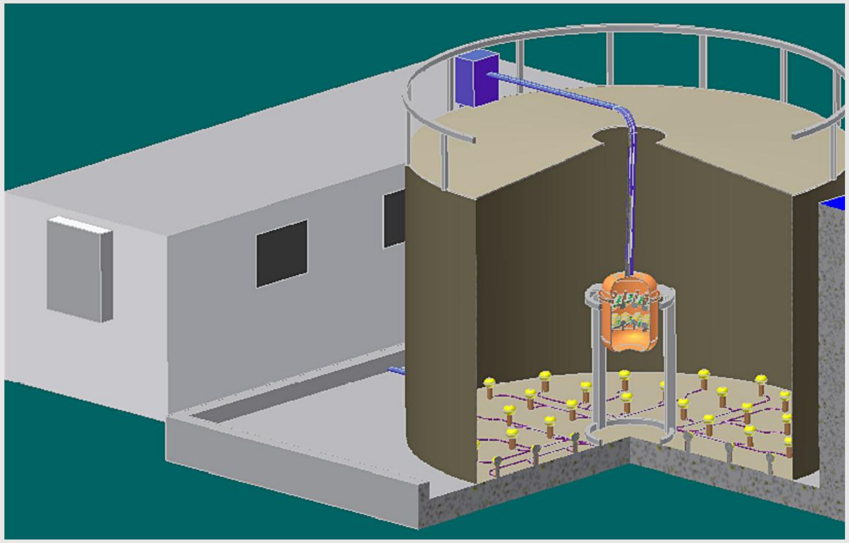
at SNS:
LXe, LAr

- First: 2-phase LXe, ~100kg, in borehole at ~45m





- Later: ~1ton,1-phase LAr/NE for longer term measurements



- *or perhaps ~10kg LAr up close, soon?*

Summary of efforts

at Fermilab/BNB and ORNL/SNS:

SNS:
- high flux near detector with low n backgrounds encouraging,
- first neutrino measurements but large open space is a challenge
- initial tests with compact detectors could discover CENNS
- Cost: ~$2-3M, Timescale 2015 for first results

Fermilab:
- flux from BNB lower, but proximity to target/source can perhaps offset
- open space may be more easily obtained for larger detectors
- Cost ~$2M, Timescale 2018 for first results with miniCLEAN detector

- 2 strong efforts on existing DAR sources
- investments made from those labs and other supporting institutions
- much progress in last few years to apply det. tech and understand backgrounds
- discovery within few years possible with more support
- then to an exciting physics program

Thanks to all who provided material for this talk.!

Extras

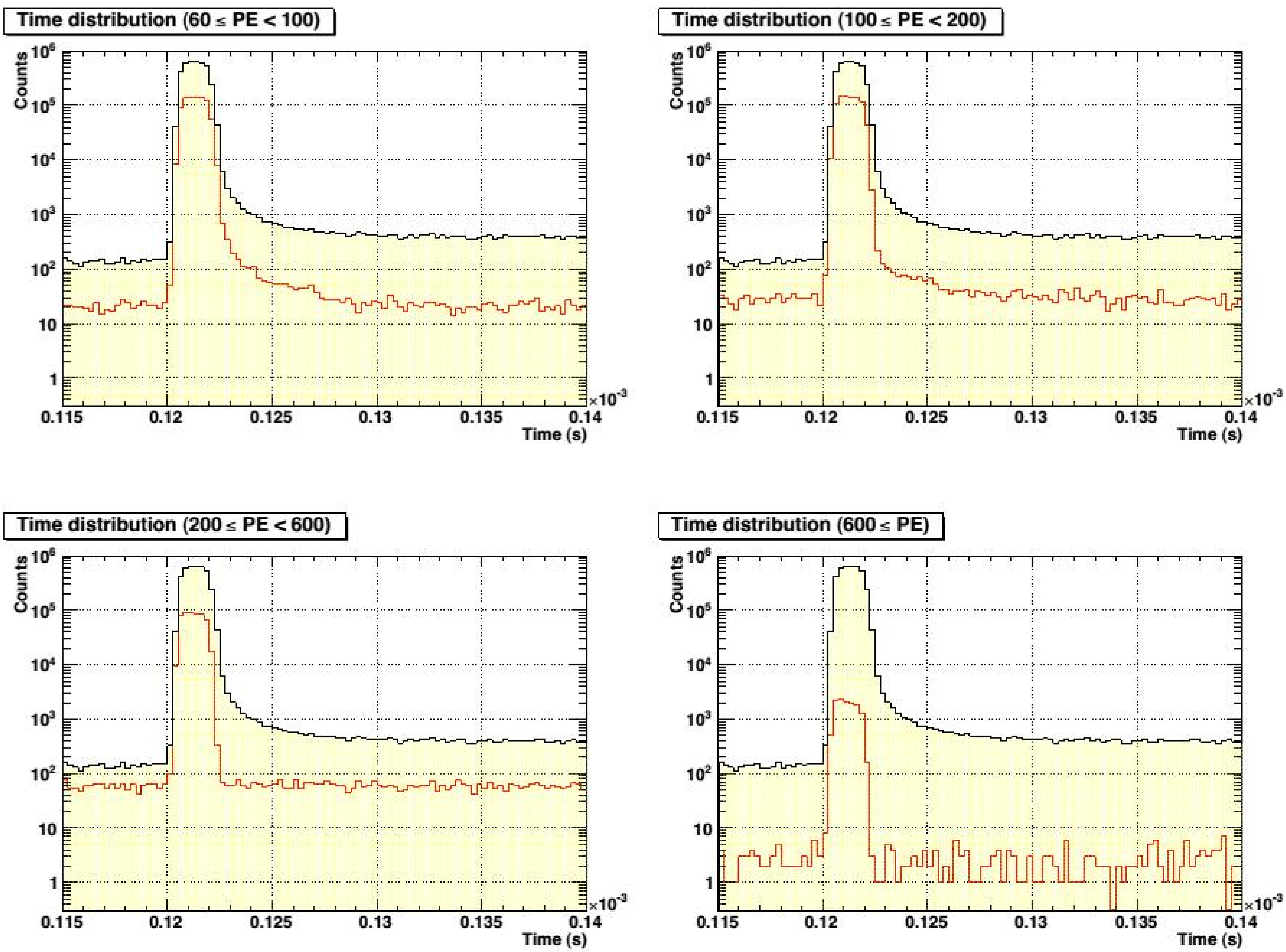


FIG. 12. The time distribution of events in a given PE group in the beam window (red trace). The black trace is the distribution for PE > 30 and is the same in each plot.